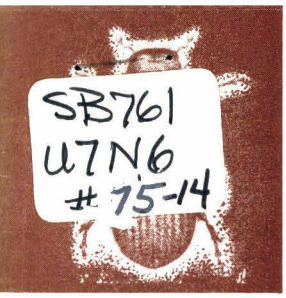
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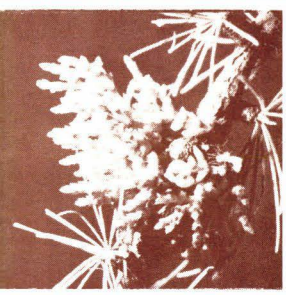

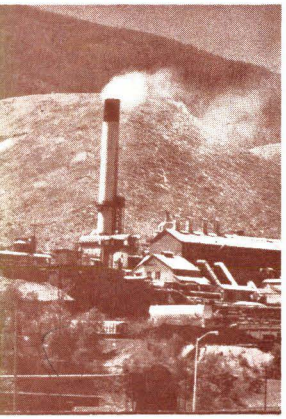

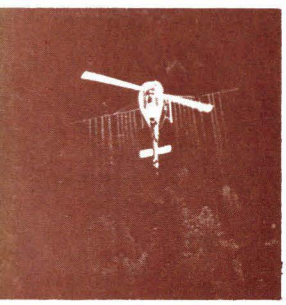

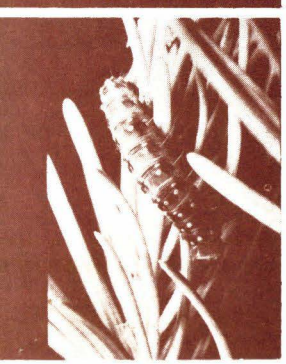

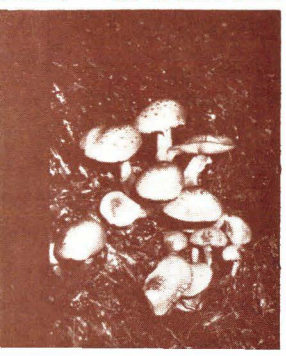

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FOREST INSECT AND DISEASE STATUS PRIOR TO OPERATION OF A MAGNESIUM PLANT IN NORTHEASTERN WASHINGTON

By

Clinton E. Carlson, Plant Pathologist and
Carma J. Gilligan, Biological Laboratory Technician

ABSTRACT

An evaluation to establish baseline data on forest insect and disease activity near a magnesium plant under construction in northeastern Washington was initiated in 1974. The plant will emit significant amounts of sulfur dioxide. Data indicates that several fungal and insect species are at low populations. Needle retention appears normal on ponderosa pine and Douglas-fir. Some tip necrosis was found on pines and histological analysis of needles revealed a pollutant syndrome. Tissue analyses indicated total sulfur in pine and fir needles is about twice that found in "clean" areas in Montana. Sulfur dioxide may be drifting in from Spokane, Washington, or Trail, B.C., Canada. In spite of evidence of a small amount of sulfur pollution at present, the forested area in general appears in good health. The data will be a good baseline to which future evaluations can be compared after the magnesium plant begins production.

INTRODUCTION

Northwest Alloys, a subsidiary of the Aluminum Company of America, is constructing a facility to produce magnesium and silicon at Addy, Washington. Details of the processes are given in an environmental impact statement (Washington DOE, 1973). Sulfur dioxide, well recognized for its phytotoxic properties, will be released at several points and may reach concentrations known to cause vegetation damage (Mathematical Sciences Northwest, 1973). Because much of the nearby surrounding forested area is administered by the USDA, Forest Service, the Colville National Forest requested that studies be undertaken prior to magnesium plant operation so that current conditions of the forest can be compared to the conditions under SO_2 stress in following years. Four different aspects of background monitoring were considered:

1. An in-depth ecological study to determine plant species, frequency, soil characteristics, etc., to be done by contract to Washington State University;

2. Air monitoring for current SO_2 concentrations, wind movement, temperatures, and relative humidities, also to be done by WSU;

3. Field surveys to assess indigenous forest insects, diseases, mimicking SO_2 symptoms, and general condition of representative vegetation, to be done jointly by WSU and Forest Service specialists; and

4. Detailed sulfur analyses, histological studies, and false color aerial photography of the area, to be done by Forest Service specialists. Details on items 1, 2, and 3 are given in a research proposal (WSU, 1974) and for item 4 in a Forest Service memorandum from Clinton E. Carlson to Dr. Ben Zamora, Washington State University, dated March 20, 1974.

This report documents Forest Service accomplishments of items 3 and 4 for field season 1974. Specifically, the objectives were:

1. Assess current status of indigenous forest insects, diseases, and abiotic stresses mimicking SO_2 injury.

2. Determine current total sulfur in foliage of representative conifers.

3. Examine in detail the histological responses of conifer needles to existing abiotic stresses.

4. Obtain baseline aerial false-color photography, stereo coverage, of the entire area in which future SO_2 damage may occur.

MATERIALS AND METHODS

Current Status of Indigenous Forest Insects, Diseases, Abiotic Stresses, and Foliar Sulfur Content

Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) and ponderosa pine *(Pinus ponderosa* Laws.) were chosen as biological indicators of potential future SO_2 damage to forests. Both are numerous in the study area and are reported to be moderately sensitive to SO_2 (Scheffer and Hedgecock, 1955). All collections were made in late August 1974, adjacent to 13 permanent ecological study plots established by WSU (Figure 1). Approximately 3 to 5 pounds of foliage were collected from two crown aspects (north and south) from each of two Douglas-fir and ponderosa pine dominant or codominant on the site. However, at plot 5, four representatives of each species were sampled, while at plot 10, only Douglas-fir was present. In all cases the location of each sample tree was referenced and each tree was permanently numbered with a metal tag. Branches cut in each case possessed foliage originating in at least 4 separate consecutive years for pine and 6 years for fir and included 1974 needles. Collected samples were kept separate and transported to cold storage in Missoula, Montana, prior to intensive laboratory evaluation.

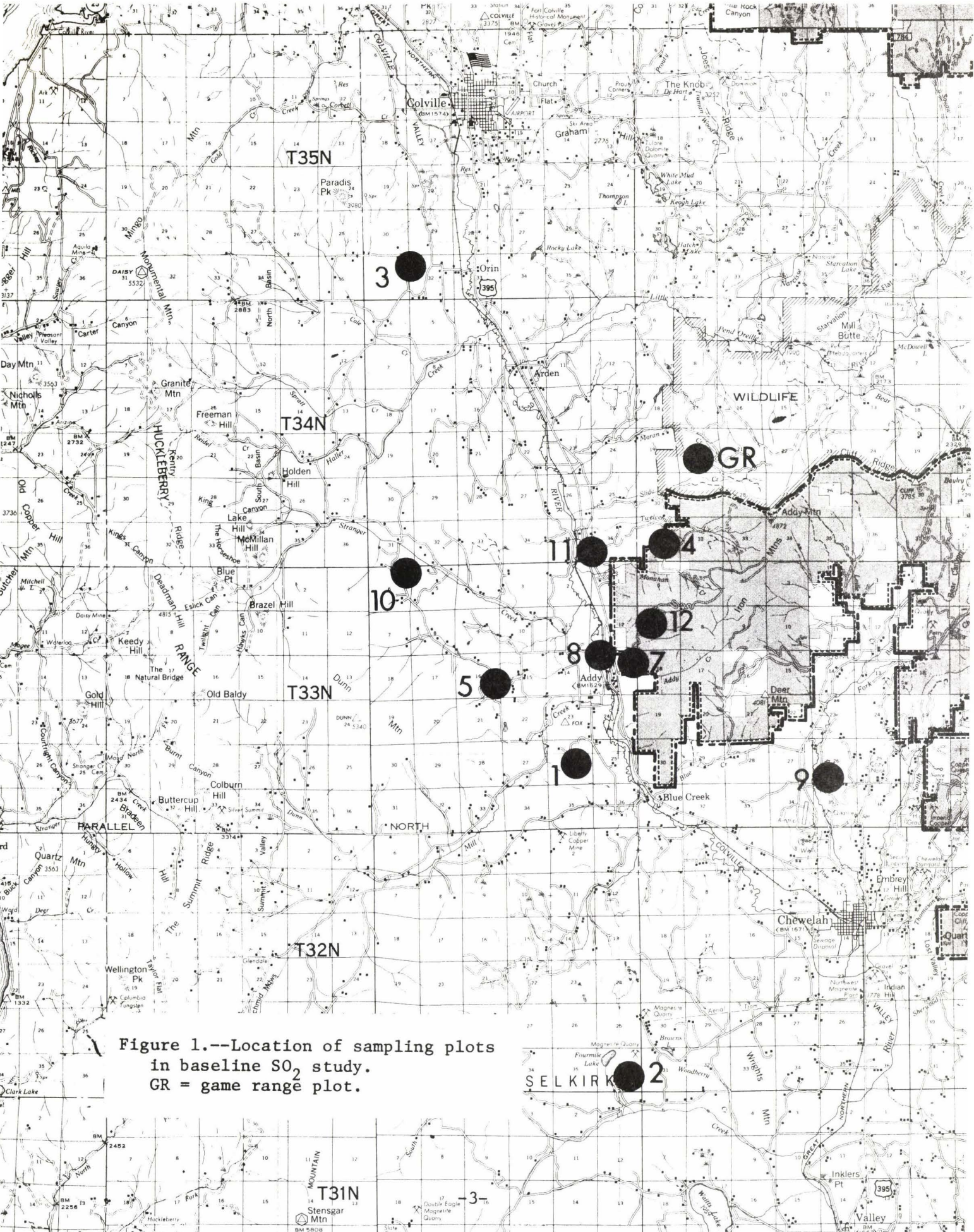

Figure 1.--Location of sampling plots in baseline SO_2 study.
GR = game range plot.

Laboratory analysis consisted of intensive, systematic evaluation of several agents affecting conifer foliage. All samples were maintained separately by plot, tree, species, and crown aspect. The following operational sequence was done on each sample:

1. On each of five branches, the number of internodes supporting needles was counted. However, this was limited to 4 years' growth on pine and 6 years on fir. The average number of internodes supporting foliage was recorded.

2. Each branch in each sample was next cut into internode segments including only 1974, 1973, 1972, and 1971 growth. On each of five randomly selected segments of each age, the total number of needles attached was counted. Then the number missing was counted by tabulating basal scars. Average proportion needles present was recorded for each year's growth.

3. Needles were stripped from each internode and kept separate by year of origin. One hundred needles were randomly selected from each lot and each was evaluated for the following: abiotic tip burn, basal necrosis, *Rhabdocline* sp., *Lophodermium* sp., *Elytroderma deformans*, other fungi; pine needle scale, (*Phenacaspis pinifoliae*); Cooley spruce gall aphid (*Adelges cooleyi*); a weevil (unidentified); basal scale (*Matsucoccus secretus* Morrison); a basal needle midge (unidentified); and other insects. The proportion healthy or damaged by each of these agents was recorded.

4. From each lot of needles 20 to 30 grams (fresh weight) were dried for 48 hours in a forced-draft oven at 85°F., ground to pass a 40-mesh screen, and sent to CH_2M Hill Corporation at Belleview, Washington, for total sulfur analysis (Blancher, et al., 1965).

Histological responses

Needles exhibiting abiotic tipburn were evaluated microscopically to assess cellular response. Two-millimeter segments were taken from the transition zone [1/], dehydrated through a tertiary butyl alcohol series, embedded in paraffin, and sectioned longitudinally and transversely at 10 microns. Serial sections were stained in Feulgens, counterstained in fast green, and observed through a phase contrast microscope.

False-color aerial photography

An area 5 miles wide (east-west) by 10 miles long (north-south) centered around the magnesium plant was aerially photographed with Kodak Aerochrome Infrared (film 2443) at a scale of 1:8000. Full stereo coverage on a 9- by 9-inch format was accomplished.

1/ The transition zone is that portion of a tip-burned needle at the junction of necrotic and healthy tissue. It includes green, yellow, and necrotic tissue.

RESULTS AND DISCUSSION

Current Status of Indigenous Forest Insects, Diseases, Abiotic Stresses, and Foliar Sulfur Content

Data for each variable measured was analyzed by analysis of variance. [2/] Five factors tested were plots, species, trees, crown position, and age of foliage (Table 1). Probably the most relevant data sort is that in which means for foliage age are listed by tree species. Here the variables upon which SO_2 is known to have an effect are clearly seen in background terms. Needle retention declines and tip-burn increases as age of tissue increases in both Douglas-fir and ponderosa pine. Ponderosa pine generally lost a greater proportion of needles over time than Douglas-fir, and was affected to a greater degree by foliage-feeding insects. Virtually no foliage fungi were observed. [3/] Of the needles that were retained, those on Douglas-fir tended to remain healthy, while pine foliage showed a rapid drop with age.

It is particularly important to note the means for total sulfur content. Regardless of foliage age, total sulfur remained constant over time.

Airborne SO_2 may accumulate in leaf tissue, and over time the older needles may have considerably higher total sulfur than will the younger.

Statistical significance of each of the factors for the different variables is shown in Table 2. Crown position was not a significant factor for any of the variables tested and variability between trees was significant in only one case.

Histological responses

Tip-burned needles of varying ages from 11 ponderosa pine and three Douglas-fir trees were sectioned and studied histologically (Table 3.)

In seemingly direct conflict with the data so far presented, all of the ponderosa pine specimens sectioned clearly exhibited a typical pollutant-caused syndrome within the vascular tissues. Transfusion parenchyma and albuminous cells were extensively hypertrophied and phloem sieve elements also were affected. Damage to the vascular system extended into the region of healthy mesophyll. In our lab and field studies, winter and drought damage never produced this type of syndrome in the vascular cylinder. [4/] Rather, in winter-drought damaged specimens, the vascular area appears intact and unaffected. One of the Douglas-fir showed pollutant syndrome while the other two were interpreted as winter-drought damaged.

2/ All data is stored on magnetic cards on file in Region 1, USFS.

3/ Subjective field examinations indicated the presence of foliar fungi; but midcrown systematic sampling did not.

4/ Manuscript in preparation.

Table 1.--Baseline data on forest insects and diseases near Addy, Washington.

Means for factors by variables

Variable [1]	Plot number											
	1	2	3	4	5	5a	7	8	9	11	12	Game Refuge
Int. needle ret.	5.000	4.900	5.000	5.000	5.000	4.700	5.000	5.000	4.600	5.000	4.900	5.000
Needle ret.	.820	.820	.730	.770	.750	.790	.670	.830	.830	.860	.840	.780
Tip-burn	.003	0	.031	.068	.120	.028	.080	.065	.026	.004	.072	.001
Basal necrosis	.028	0	.082	.041	.032	.089	.093	.061	0	.002	.072	.041
Rhabdocline	0	0	0	0	0	0	0	0	0	0	0	0
Lophodermium	0	0	0	0	0	0	0	0	0	0	0	0
Elytroderma	0	0	0	0	0	0	0	0	0	0	0	0
Other fungi	0	0	0	0	0	0	0	0	0	.002	.003	0
Pine scale	.007	.022	.057	.076	.068	.011	.049	.015	.001	.014	.002	.007
Aphid	0	0	0	.001	.002	0	0	.001	.001	0	0	0
Weevil	.047	.012	.063	.056	.073	.071	.098	.061	.031	.100	.087	.054
Basal scale	.111	.067	.031	.042	.028	.069	.098	.069	.084	.159	.031	.162
Midge	.013	.011	.008	.003	.003	.006	.005	.001	.005	.004	.008	.007
Other insects	.013	.008	.018	.023	.036	.034	.028	.020	.019	.013	.023	.024
Healthy	.785	.883	.745	.642	.774	.725	.659	.772	.846	.739	.768	.728
Total sulfur	.034	.035	.066	.018	.039	.036	.051	.029	.049	.041	.033	.022

Variable [1]	Species		Tree number		Crown position		Year			
	Douglas-fir	Ponderosa pine	Tree 1	Tree 2	North	South	1974	1973	1972	1971
Int. needle ret.	5.890	3.940	4.920	4.920	4.880	4.960	--	--	--	--
Needle ret.	.862	.719	.791	.790	.794	.788	.952	.839	.734	.639
Tip burn	0	.064	.040	.025	.033	.032	.004	.003	.003	.074
Basal necrosis	0	.090	.047	.043	.044	.046	.001	.014	.058	.107
Rhabdocline	0	0	0	0	0	0	0	0	0	0
Lophodermium	0	0	0	0	0	0	0	0	0	0
Elytroderma	0	0	0	0	0	0	0	0	0	0
Other fungi	0	.001	.001	0	0	.001	0	0	.001	0
Pine scale	0	.055	.024	.031	.029	.026	.005	.003	.038	.034
Aphid	.001	0	.001	0	0	.001	.001	0	.001	0
Weevil	0	.126	.054	.072	.062	.063	.025	.062	.097	.067
Basal scale	0	.158	.075	.083	.073	.085	.005	.049	.124	.139
Midge	0	.014	.006	.007	.008	.006	.013	.005	.007	.003
Other insects	.040	0	.020	.023	.022	.022	.018	.021	.027	.020
Healthy	.959	.552	.751	.760	.753	.759	.918	.803	.671	.630
Total sulfur	.042	.034	--	--	.040	.035	.038	.035	.039	.039

1/ Values for all variables except total sulfur are percent; total sulfur is percent on dry weight basis.

Table 1.--Baseline data on forest insects and diseases near Addy, Washington
Means for factors by variables, con.

Variable	Douglas-fir				Ponderosa pine			
	1974	1973	1972	1971	1974	1973	1972	1971
Int. needle ret.	--	--	--	--	--	--	--	--
Needle ret.	0.986	0.908	0.790	0.766	0.918	0.770	0.678	0.511
Tip burn	0	.001	.001	0	.009	.045	.056	.149
Basal necrosis	0	0	0	0	.002	.003	.115	.214
Rhabdocline	0	0	0	0	0	0	0	0
Lophodermium	0	0	0	0	0	0	0	0
Elytroderma	0	0	0	0	0	0	0	0
Other fungi	0	0	0	0	0	.001	.002	.001
Pine scale	0	0	0	0	.011	.066	.075	.067
Aphid	.001	0	.001	0	0	0	0	0
Weevil	0	0	0	0	.050	.125	.193	.134
Basal scale	0	0	0	0	.010	.098	.247	.279
Midge	0	0	0	0	.026	.010	.014	.006
Other insects	.034	.037	.050	.037	.002	.005	.003	.035
Healthy	.964	.960	.947	.964	.872	.647	.395	.295
Total sulfur	.044	.042	.042	.039	.032	.029	.035	.039

Table 2.--Baseline data on insects and diseases near Addy, Washington.
"F" values for factors

Variable	Plots	Species	Trees	Crown position	Foliage age	Foliage age within species
Int. needle ret.	1.50	936.00**1/	.02	1.38	--	--
Needle ret.	-13.50**	-289.00**	-.07	-.05	-257.00**	-140.00**
Tip burn	3.40**	44.27**	2.62	.01	9.48**	9.52**
Basal necrosis	10.00**	207.00**	.32	.06	58.00**	58.00**
Rhabdocline	1.00	1.00	1.00	1.00	1.00	1.00
Lophodermium	1.00	1.00	1.00	1.00	1.00	1.00
Elytroderma	1.00	1.00	1.00	1.00	1.00	1.00
Other fungi	1.06	2.66	1.50	.17	.57	.66
Pine scale	6.81**	83.00**	1.45	.19	6.08**	6.08**
Aphid	1.31	6.69**	2.41	.74	1.30	1.30
Weevil	6.91**	492.00**	9.56**	.01	27.00**	27.00**
Basal scale	8.74**	306.00	.75	1.79	48.00	48.00
Midge	1.25	35.00	.18	.42	3.57	3.57
Other insects	3.81**	208.00	1.71	0	2.08	2.05
Healthy	-6.92**	-749.00	-.35	-.16	-78.00**	-76.00**
Total sulfur	5.69**	6.12*	2.20	.25	.52	.60

1/* - Significant at .05 level of probability
** - Significant at .01 level of probability

Table 3.--Results of histological study of ponderosa pine and Douglas-fir needles.

Slide No.	Plot	Tree	Species	Crown	Origin of needles	Syndrome		Total[1] sulfur	High[2] sulfation plate
						Pollution	Winter/ drought		
26c(2-5)	11	H7	PP	S[3]	1973	X		NA	0.06
176L(2-14)	8	H12	PP	S	1971	X		.08	.04
320L(4-4)	7	A103	PP	S	1971	X		NA	.06
319c	7	A103	PP	S	1972	X		NA	.06
327	5	H24	PP	N	1974	X		NA	.04
328	5	H24	PP	N	1971	X		NA	.04
340	7	A103	PP	N	1971	X		NA	.06
351	7	A105	PP	S	1972	X		.06	.06
112	1	H29	PP	S	1971	X		NA	.06
26c	11	H7	PP	S	1973	X		NA	.06
36c	9	H34	PP	N	1971	X		.04	.07
181L	4	H14	DF	S	1974	X		.01	.08
194L	12	A106	DF	N	1973		X	NA	.01
146c	8	H10	DF	N	1973		X	NA	.04

1/ Parts per million dry weight
2/ $mg/cm^2/day$
3/ S = South, N = North

We were surprised that a pollutant syndrome should occur in this background area. Field investigations indicated in general that the pines and firs are in a healthy condition. However, the sulfation plate system installed and reported on by Dr. Pack [5] indicates that abnormally high amounts of airborne sulfur currently are present in the Addy area. A high of 0.12 $mg/cm^2/day$ and several values exceeding 0.03 $mg/cm^2/day$ were recorded throughout the area. Control data obtained in Montana relative to another study (Carlson, et al., 1974) were always less than 0.02 $mg/cm^2/day$. Sixty of 78 readings at Addy were greater than background in Montana, and 14 were greater by a factor of 2 or more than Montana readings. There may be enough sulfur currently in the ambient air at Addy to cause a small amount of tip necrosis.

An attempt was made to relate total sulfur in the sample to the histological syndrome (Table 3). Unfortunately, in most cases the data was not available (only one-half the available samples were analyzed for total sulfur) and no meaningful relationship could be developed. However, total sulfur data in ponderosa pine collected in the Montana study

5/ System established in summer 1974 and reported at the February 1975 Steering Committee meeting.

(Carlson, et al., 1974) for controls averaged 0.01 percent with little variability. In the Addy area, total sulfur averaged three to four times that found in Montana (analytical methods identical and by same company). This is evidence that conifers near Addy may already have accumulated abnormally high sulfur content. Data from conifers in Alaska support this contention. 6/ High sulfation plate data as reported by Pack also is given for each plot (Table 3). Generally, the sulfation rate was two to four times that found in Montana control areas. However, because of the nonspecificity of the sulfation plate method, instrumental continuous sampling for SO_2 is necessary in the forested areas to delineate peak values over time.

The histological effects reported here may or may not have been caused by SO_2. Certainly, a strong case may be made substantiating why SO^2 may not be the cause. Nevertheless, we have studied pine needle necrosis in areas definitely diagnosed as winter damaged and the syndrome is entirely different from that observed in the Addy area.

False-color aerial photography

The false-color photography was completed as scheduled on July 30, 1974. This material was duplicated and a copy given to Alcoa at their expense. In addition, black/white stereo prints will be made for use in calendar year 1975. To date, we have not made any quantitative interpretations of indigenous insect and disease damage. We anticipate this photography will be of most value for comparative purposes after the magnesium facility begins operation.

CONCLUSIONS

The data collected to date should represent a firm base from which to assess possible future impacts from the magnesium plant. Sulfation plate data indicate above-normal sulfur levels exist in the area now. It is conceivable they are transported from Trail B.C., Canada; Spokane, Washington; or even from the Seattle-Tacoma area. Tip necrosis observed in 1974 may have been caused in part by sulfur from these sources. Certainly another year's baseline data on ambient sulfur and histology of tip necrosis is necessary. Continuous SO_2 monitoring by methods other than sulfation plates is warranted in the forested zones and future plans should consider this option.

It is strongly recommended that in addition to repeating in total the measurements taken in 1974, a system of permanent ground photo points be established to record the visual condition of a number of sample trees.

6/ Personal communication with Tom Laurent, Juneau, Alaska, USDA, Forest Service.

LITERATURE CITED

Blancher, R. W., G. Rehm, and A. W. Caldwell, 1965. Sulfur in plant materials by digestion with nitric and perchloric acid. Soil Science Soc. Amer. Proc. 29:71.

Carlson, C. E., M. D. McGregor, and N. M. Davis, 1974. Sulfur damage to Douglas-fir near a pulp and paper mill in western Montana. USDA, Forest Service, Missoula, Montana. 41 pp.

Mathematical Sciences Northwest, Inc., 1973. Environmental analysis, proposed northwest alloys magnesium plant, Addy, Washington. Olympia, Washington. 87 pp.

Scheffer and Hedgecock, 1955. Injury to northwestern forest trees by sulfur dioxide from smelters. Tech. Bull. #1117, USDA, Forest Service.

Washington Department of Ecology, 1973. Environmental impact statement, proposed northwest alloys magnesium plant, Addy, Washington. Olympia, Washington. 303 pp.

Washington State University, 1974. Project proposal for Addy SO_2 monitoring. Agricultural Exp. Sta. and Coll. Eng., Pullman, Washington. 9 pp.